SECTION 616
STRUCTURAL STEEL

616.01 DESCRIPTION.

The work consists of fabricating, furnishing, delivering and erecting structural steel.

616.02 MATERIALS.

Material shall meet the following:

Item	Section
Structural Carbon Steel	834.01 A
High Strength, Low-Alloy Steel	834.01 B
High Strength, Low-Alloy Structural Steel With 50,000 psi Minimum Yield Point to 4 inch thick	834.01 C
Structural Steel for Pins and Rollers	834.01 E
Steel Forgings	834.02 A
Steel Castings	834.02 B
Gray Iron Castings	834.02 C
Malleable Castings	834.02 D
Bronze Bearing and Expansion Plates	834.02 F
Cast Aluminum	834.02 H
Lead Sheet and Plates	834.02 I
Brass Sheet	834.02 J
Copper Sheet	834.02 K
Structural Bolts, Nuts, and Washers	834.03
Direct Tension Indicators	834.03 C

Welded Stud Shear Connectors shall meet the most recent AASHTO Standard Specifications for Highway Bridges.

616.03 CONSTRUCTION REQUIREMENTS.

A. **Shop Detail Drawings.** The Contractor shall prepare all work drawings (detailed shop drawings, erection diagrams, etc.) required for the fabrication and erection of steel.

Shop drawings consist of detailed plans showing dimensions and sizes of materials for fabrication, bolt lists for field erection, a match-marking diagram, and a complete field erection plan.

Shop drawings shall be 22 inches by 36 inches. Shop drawings generated by a computer automated drafting (CAD) system may be submitted on 11-inch by

17-inch detail sheets. Each sheet shall be consecutively numbered and have a title giving the project number, bridge number, the fabricator's name, the fabricator's contract number, and a brief description of the details shown on the sheet.

Two sets of drawings, or more if required, shall be submitted to the Engineer for approval 14 days, or as specified in the Contract, before fabrication. The Engineer will return one set approved or with corrections and changes noted. Drawings containing corrections or changes shall be resubmitted in duplicate until approved by the Engineer. Additional time required to make adjustments to shop drawings due to the Contractor's errors or omissions is the responsibility of the Contractor. Additional work or file copies of approved drawings shall be provided as requested.

The Contractor shall be responsible for the accuracy of shop drawings and report any discrepancies to the Engineer for revision and correction before fabrication is begun. Any material ordered or work done by the Contractor before the drawings have been approved shall be at the Contractor's risk.

The Engineer's review and approval applies only to the requirements for strength and arrangements of parts and details and does not relieve the Contractor of full responsibility for the accurate assembly and fitting of all structural members.

B. **Shop Inspection.**

Shop inspection personnel shall meet the qualifications stated in the latest ANSI/AASHTO/AWS D1.5 Bridge Welding Code regarding inspection personnel qualifications.

Shop inspection of welded plate girders will be required. Shop inspection of other steel members will be required when ordered by the Engineer. The Contractor shall provide the Engineer at least 3 weeks notice before beginning fabrication.

The Contractor shall furnish facilities for the inspection, allow the Inspector access to all areas, and furnish at least two 4-inch by 18-inch samples of each grade and brand of structural steel for testing without charge.

The Inspector shall have authority to reject materials or work which do not meet the specified requirements.

Acceptance of materials or work by the Inspector shall not prevent subsequent rejection if found defective.

C. **Fabrication.**

1. **General.** Fabrication shall meet the latest AASHTO/AWS D 1.5 Bridge Welding Code except as changed by this Specification. For structures that carry railroad traffic, the structural steel shall be fabricated according to the A.R.E.M.A. Specifications.

2. **Bolts.** Permanent field connections shall be made using high-strength bolts. The same type of fastener shall be used throughout the structure.

   The diameter of the bolt holes shall be 1/16 inch greater than the diameter of the bolts used. Bolts transmitting shear shall be threaded to such a length that

not more than one thread is within the grip of the metal. The bolts shall be of a length to extend entirely through the nuts but not more than 1/4 inch beyond the face of the nut. One lock washer shall be placed under the nut of each bolt connecting handrails. A hardened washer shall be installed over slotted holes.

Galvanized nuts shall be checked to verify that a visible lubricant is on the threads.

Black bolts shall be oily to the touch when delivered and installed.

Weathered or rusted bolts and nuts that are not lubricated shall be cleaned and relubricated before installation. Recleaned or relubricated bolt, nut and washer assemblies shall be retested according to Section 616.03 C.3.a.

3. **Connections.** The assembly of structural joints using high strength steel bolts tightened to a high tension shall meet the following requirements:

   a. The rotational-capacity test described in Section 834.03 B. shall be performed on each rotational-capacity lot before starting bolt installation. Hardened steel washers are required for tests, but they may not be required in the actual installation procedures.

      A Skidmore-Wilhelm Calibrator or an acceptable equivalent tension measuring device will be provided by the Department at each project site during erection. Periodic testing (at least once each working day when the calibrated wrench method is used) shall be performed by the Contractor and verified by the Engineer to assure compliance with the installation test procedures of Section 616.03 C.3.b for Turn-of-Nut Tightening, Calibrated Wrench Tightening, and Direct Tension Indicator Tightening. Bolts too short for the Skidmore-Wilhelm Calibrator may be tested using direct tension indicators. The direct tension indicators must be calibrated in the Skidmore-Wilhelm Calibrator using longer bolts.

   b. Bolted parts shall fit firmly together when assembled. Contact surfaces, including those adjacent to the washers, shall be descaled or carry the normal tight mill scale. Contact surfaces shall be free of dirt, oil, loose scale, burrs, pits and other defects that would prevent solid seating of the parts. Bolts shall be installed with nuts on the interior side of the web and on the upper side of the flange.

      Bolts shall be installed with a hardened washer under the nut or bolt head, whichever is the element turned in tightening. A flat washer may be used when the abutment surface adjacent to the bolt head or nut does not have a slope of more than 1:20 with respect to a plane normal to the bolt axis. Where an outer face of the bolted parts has a slope of more than 1:20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for lack of parallelism. All fasteners shall be tightened to give at least the required minimum bolt tension values shown in Table 1 on completion of the joint. Tightening shall be done with properly calibrated torque wrenches, the turn-of-nut method, or direct tension indicators.

Table 1
Required Fastener Tension

Bolt Size (inches)	Minimum Bolt Tension* (pounds)
1/2	12,000
5/8	19,000
3/4	28,000
7/8	39,000
1	51,000
1-1/8	56,000
1-1/4	71,000
1-3/8	85,000
1-1/2	103,000

*Equal to 70% of specified minimum tensile strength of bolts (as specified in ASTM Specifications for tests of full size A-325 bolts with UNC threads loaded in axial tension).

c. High tensile strength bolts (AASHTO M-164) which have been tightened previously to the minimum bolt tension specified in Table 1 shall not be reused. Any high tensile strength bolt which must be loosened and retightened for any reason shall be replaced with a new bolt and nut. The Contractor shall bear the cost of bolts and nuts replaced under this requirement.

(1) Turn-of-Nut Tightening. When the turn-of-nut method is used to provide the bolt tension specified in Table 1, all bolts in the joint shall first be brought to a “snug tight” condition to ensure the parts of the joint are in full contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a worker using an ordinary spud wrench. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified in Table 2 with tightening progressing systematically from the rigid part of the joint to its free edges. During this operation, there shall be no rotation of the part not turned by the wrench.

Table 2
Nut Rotation from Snug Tight Condition (a), (b)
Disposition of Outer Faces of Bolted Parts

Bolt Length (underside of head to end of bolt)	Both faces normal to bolt axis	One face normal to both axis and other sloped not more than 1:20 (beveled washer not used)	Both faces sloped not more than 1:20 from normal to the bolt axis (beveled washers not used)
Up to and inc. 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters (c)	2/3 turn	5/6 turn	1 turn

(a) Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be plus or minus 30 degrees; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45 degrees.

(b) Applicable only to connections in which all material within the grip of the bolt is steel.

(c) No research has been performed by the Research Council on Riveted and Bolted Structural Joints to establish the turn-of-nut procedure for bolt lengths exceeding 12 diameters. Therefore, the required rotation must be determined by actual test in a suitable tension measuring device which simulates conditions of solidly fitted steel.

(2) Calibrated Wrench Tightening. Calibrated wrench tightening may be used only when installation procedures are calibrated on a daily basis and when a hardened washer is used under the element turned in tightening.

Calibrated wrenches shall be set to provide a tension not less than 5% in excess of the minimum tension specified in Table 1. Calibration shall be accomplished in a device capable of indicating actual bolt tension by tightening three typical bolts of each diameter, length and grade from the bolts being installed and with a hardened washer from the washers being used in the work under the element

turned in tightening. Wrenches shall be recalibrated when significant difference is noted in the surface condition of the bolt threads, nuts or washers. It shall be verified during actual installation in the assembled steelwork that the wrench adjustment selected by the calibration does not produce a nut or bolt head rotation from snug tight greater than that permitted in Table 2. If manual torque wrenches are used, nuts shall be turned in the tightening direction when torque is measured.

Bolts shall be installed with hardened washers under the element turned in tightening bolts in all holes of the connection and brought to a snug tight condition. Following this initial tightening operation, the connection shall be tightened using the calibrated wrench. Tightening shall progress systematically from the most rigid part of the joint to its free edges. The wrench shall be returned to "touch up" previously tightened bolts which may have been relaxed as a result of the subsequent tightening of adjacent bolts until all bolts are tightened to the prescribed amount.

(3) Direct Tension Indicator Tightening. Direct tension indicators shall be as specified in Section 834.03 C. A representative sample of not less than three direct tension indicator devices for each diameter and grade of fastener to be used in the work shall be assembled in a calibration device capable of indicating bolt tension. The test assembly shall include flat hardened washers, if required in the actual connections, arranged as those in the actual connections to be tensioned. The calibration test shall demonstrate that the device indicates a tension not less than 5% greater than required by Table 1.

Manufacturer's installation procedure shall be followed for installation of bolts in the calibration device and in all connections. Special attention shall be given to proper installation of flat hardened washers when direct tension indicator devices are used with bolts installed in oversize or slotted holes and when the load indicating devices are used under the turned element.

Bolts shall be installed in all holes of the connection and brought to snug tight condition. Snug tight is indicated by partial compression of the direct tension indicator protrusions. All fasteners shall then be tightened, progressing systematically from the most rigid part of the connection to the free edges in a manner that will minimize relaxation of previously tightened fasteners. In some cases, proper tensioning of the bolts may require more than a single cycle of systematic partial tightening prior to final tightening to deform the protrusion to the specified gap.

(4) **Alternate Design Bolt Tightening.** Fasteners which incorporate a design feature intended to indirectly indicate the bolt tension or to automatically provide the tension required by Table 1 shall meet the requirements of Section 834.03 B. Verification testing using a representative sample of not less than three bolt and nut assemblies of each diameter, length and grade to be used in the work shall be performed at the job site in a device capable of indicating bolt tension.

The test assembly shall include flat-hardened washers, if required in the actual connection, arranged as in the actual connections to be tensioned. The verification test shall demonstrate that each bolt develops a tension not less than 5% greater than the tension required by Table 1. Manufacturer's installation procedure shall be followed for installation of bolts in the calibration device and in all connections. Periodic retesting shall be performed when ordered by the Engineer.

When alternate design fasteners which are intended to control or indicate bolt tension of the fasteners are used, bolts shall be installed in all holes of the connection and initially tightened sufficiently to bring all plies of the joint into firm contact but without yielding or fracturing the control or indicator element of the fasteners. All fasteners shall then be further tightened, progressing systematically from the most rigid part of the connection to the free edges in a manner that will minimize relaxation of previously tightened fasteners. Proper tensioning of the bolts will require more than a single cycle of systematic partial tightening prior to final twist-off of the control or indicator element of individual fasteners. If twist-off occurs prior to the final tightening cycle, the individual fastener shall be replaced with a new one.

4. **Marking and Shipping.** Each member shall be painted or marked with an erection mark for identification, and an erection diagram shall be furnished showing the erection marks. Bolts of one length and diameter, and loose nuts and washers of each size shall be packed separately. Pins, small parts, small packages of bolts, washers, and nuts shall be shipped in suitable containers. A list and description of the material shall be plainly marked on the outside of each container. The loading, transporting, unloading, and storing of structural material shall be conducted so the metal is kept clean without stressing, deforming, or damaging the structural members.

   Long steel members shall be handled by placing saddles at approximately the quarter points and during storing and shipping, blocking shall be placed at intervals that prevents sag and distortion. Rolled beams and built-up plate girders shall be stored, shipped, and handled in a vertical position.

5. **Shop Painting.** All required painting shall meet Section 630.

6. **Blast Cleaning of Unpainted Steel.** After fabrication with AASHTO 270 Grade 50 W steel for unpainted applications, the exterior faces of outside beams or girders (including stiffeners and flanges) and other steel readily exposed to view shall be blast cleaned as specified in the Steel Structures Painting Council Surface Preparation Specification "No. 6 Commercial Blast Cleaning," SSPC-SP 6. A corrosion inhibitor shall not be used.

   Blast cleaning shall be included in the Contract Price Bid for the structural steel.

D. **Shop Welding.** Shop welding shall meet the latest AASHTO/AWS D 1.5 Bridge Welding Code except as changed by this Specification. The electroslag and electrogas welding processes shall not be used for welding bridge members.

Flange-to-web welds and shop welded splices in flanges or webs shall be performed using the automatic submerged arc and welding process.

1. **Qualification of Welders, Welding Operators, and Tackers.** As specified in Section 105.06 D. for all welding applications

2. **Built-up Plate Girders.** Web plates of built up beams and girders shall be cut to the prescribed camber with allowance for shrinkage due to cutting and welding.

   All shop butt welds in the flange plates shall be made before final fitting and welding into the girders.

3. **Nondestructive Testing.** All nondestructive testing (NDT) of welds required by the ANSI/AASHTO/AWS D1.5 95 Bridge Welding Code and by Sections 616.03 D.4 and 616.03 D.5 of the North Dakota Department of Transportation Standard Specifications, shall be the responsibility of the Contractor.

   Performance of NDT shall be done by trained personnel under the observation of the Engineer. The trained personnel shall have a minimum qualification as an American Society for Nondestructive Testing (ASNT) NDT Level II operator and two-years experience at that level. A written report of all NDT shall be submitted to the Engineer along with material certification documenting compliance of the welds with contract requirements.

   The cost of all NDT shall be included in the bid price for “Structural Steel.”

   Methods of nondestructive testing, in addition to those specified, may be used for examination of weld passes or complete welds.

   The Department may examine weld areas not designated in the Contract.

4. **Radiographic and Ultrasonic Inspection.** Groove welds in main members of built up girder structures shall be inspected by radiographic or ultrasonic testing as follows:

   a. All tension splices and all splices subject to reversals of stress shall be completely inspected.

   b. On girder and beam web splices, only 1/6 of the web depth beginning at the point or points of maximum tension and 25% of the remainder of the web depth need be tested.

   c. All compression flange splices shall be inspected.

   Welds shall be tested after grinding.

   Repaired welds shall be retested.

5. **Magnetic Particle Inspection.** At least one foot of every 10-foot length of weld and one foot of each weld less than 10 feet in length of longitudinal beam or girder web butt splices and fillet welds in main members, including

the end connections, shall be tested by the magnetic particle inspection method. Tests shall be made at random locations in the members so as to be typical for each size of weld and type of joint.

If rejectable discontinuities are found in any test length of weld, the full length of the weld or 5 feet on either side of the test length, whichever is less, shall be repaired.

Welds shall be retested after repairs are made. Retesting shall include the repaired area plus at least 2 inches on each side of the repaired area.

E. **Erection.** The structure shall be erected as follows:

1. **Handling and Storing Materials.** Stored materials shall be kept clean and properly drained. Steel shall be stored above ground on platforms, skids or other supports. Girders, beams, and long members such as columns and chords shall be supported to prevent damage from deflection. Girder sections shall be handled with beam clamps or other approved devices and wire rope slings shall not be used. On an erection contract, the Contractor shall check the material received against the shipping lists and promptly report in writing any shortages or damages. The Contractor shall be responsible for the loss of or damage to any material while in the Contractor's possession.

   AASHTO 270 rade 50 W steel to be used in unpainted applications shall be stored above ground on platforms, skids, or other supports. The steel shall be kept clean and free of all foreign materials such as grease, concrete spatter, chalk or crayon marks, dirt, or any foreign matter that may affect the metal's natural oxidation. Temporary protection shall be required during concrete operations and all operations that may affect uniform natural oxidation. Loading, transporting, and unloading of steel shall be conducted without surface damage and metal deformation.

2. **Falsework, Methods, and Equipment.** The falsework shall be designed, constructed, and maintained to support all loads. If required, the Contractor shall prepare and submit to the Engineer for approval, plans for falsework or for changes in an existing structure necessary for maintaining traffic. The submittal process shall be as specified in Section 616.03 A.

3. **Assembling Steel.** Parts shall be accurately assembled by the match marks on the shop drawings. Material shall be handled so parts are not bent, broken, or damaged. Bolts or nuts with rusted or damaged threads shall not be used. Hammering which damages or distorts the members shall not be permitted. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before members are assembled. Splice points in beam or girder spans shall be brought to proper elevation and supported in position before the fasteners are tightened. High strength bolts shall be assembled according to Section 616.03 C.3.

4. **Straightening Bent Material.** Bent members shall be returned to the fabricator for repair or replacement. Bends in main structural members shall not be straightened in the field without written permission of the Engineer.

   Straightening of bent members shall be done without producing embrittlement, fracture, or damage. All material shall be straightened cold. Plated, gal-

vanized, enameled, heat treated or cold drawn steel and copper alloys, malleable iron, tempered aluminum, or similar metals shall not be heated. Bent members that cannot be satisfactorily straightened cold shall be returned to the fabricator for repair or replacement.

Mild steel and structural grade steel may be heated when authorized in writing by the Engineer. The temperature of the heated area shall not exceed 1200°F. (a dull red) as controlled by temperature indicating crayons, liquids, or bimetal thermometers.

5. **Field Painting.** Structural steel shall be painted according to Section 630.

6. **Field Welding.** As specified in Section 105.06 D.

7. **Removal of Rust Stains.** When AASHTO 270 Grade 50 W steel is erected in unpainted condition, all rust stains on the substructure units after completing all steel and concrete work shall be removed with a concrete rust stain remover. All areas receiving applications of rust stain remover shall be flushed with water.

   Substructure units may be protected with reinforced polyethylene or similar material which shall be left in place to prevent staining until the superstructure is completed.

616.04 METHOD OF MEASUREMENT.

A. **General.** Structural metals placed in bridges or other structures will be measured by weight, length, area, or unit complete and in place.

The Contractor shall furnish calculated weights and measurements in duplicate to the Engineer for review and determination of final quantities.

Only accepted work will be measured for payment. Dimensions used will be those shown on the Plans, the approved shop drawings, or as authorized by the Engineer.

B. **Measurement by Weight.** Measurement by weight will be by the Pound. The quantity paid for will be the total weight, determined as specified. All castings and miscellaneous metal parts will be measured and paid for as Structural Steel. The following pounds per cubic foot of metal will be used as the basis of computation:

Aluminum, Cast or Wrought	173.0
Brass	534.0
Bronze, Cast	536.0
Bronze, Wrought	555.0
Copper, Sheet	558.0
Iron, Cast	445.0
Iron, Malleable	470.0
Lead, Sheet & Plate	707.0
Steel (all kinds)	490.0
Zinc, Sheet	450.0

1. **Structural Steel and Wrought Metals.** The weight of all permanent bolts 6 inches or less in length, thin nuts, field shims, ring fills, shop and field

welds, shop and field painting, galvanizing, metallizing, and all other incidental metal items for which no direct weight measurement is made will not be measured or paid for and will be included in the Contract Price Bid for Structural Steel. Except as provided, the weight will be computed from dimensions shown on the Plans, the approved shop drawings, or as authorized by the Engineer. Deductions will not be made for cuts, copes, bevels, or open holes; and allowance will not be made for mill overruns.

2. **Structural Plates.** The weight of rectangular plates (such as web plates, cover plates, batten plates, etc.) will be computed on the basis of the net length and width shown on the Plans. Allowance will not be made for planed or sheared edges.

   The weight of each plate or irregular shape will be computed on the basis of the dimensions of the smallest rectangular plate from which it can be cut. When plates are machine finished, the dimension of the plates will be the maximum machine finished dimension plus 1/8 inch for each finished surface.

3. **Structural Shapes and Bars.** The weight of all bars and structural shapes with square ends will be computed on the basis of the net section and the length as shown on the Plans.

   Identical structural shapes, less than 5 feet long, with mitered ends will be considered multiple cut. Their total weight will be computed as the weight of the shortest parent section from which they can be cut, provided the length of the parent section is not be more than 30 feet.

   Except as provided above, the weight of each structural shape with mitered ends will be computed on the basis of the section and overall length measured parallel to the axis of the shape.

4. **Pins and Rollers.** The parent section for forged segmental rollers will be considered square in section, and of the same length, width, and thickness as the finished roller.

   The weight of hot-rolled bar steel pins and rollers will be computed on the basis of the length shown on the Plans and on the basis of a diameter 1/4 inch greater than that of the finished pin or roller. The weight of cold finished bar steel pins and rollers will be computed on the basis of the net length and diameter shown on the Plans.

5. **Bolts and Tie Rods.** The weight of bolts over 6 inches long and tie rods including necessary nuts and washers used for connecting structural steel parts will be computed from the nominal weights as given in the current handbook of the American Institute of Steel Construction. These weights will be included in the weight of “Structural Steel.”

6. **Castings.** The weight of each casting will be computed from the net dimensions shown on the approved shop drawings, with an addition of 10% to compensate for fillets and overruns. Wherever machine-finished surfaces are required, an allowance of 1/8 inch in thickness will be made for each surface so finished. When cored holes are shown on the Plans, a deduction will be made for the full size of the core.

7. **Pipe.** The weight will be computed from the dimensions shown on the Plans and the nominal weights of the pipe and fittings.

8. **Sheet Metal.** The weight will be computed from the smallest rectangular area from which the developed surface can be cut.

C. **Lump Sum Basis.** When Structural Steel is measured and paid for on a "Lump Sum" basis, it includes all Structural Steel required under this Section and will not be modified unless design Plan changes are ordered by the Engineer. The following conditions will apply to the lump sum basis:

1. The estimated weight of Structural Steel computed according to Section 616.04 B will be shown on the Plans. If any change in design is made which effects the weight of material furnished, payment for the additional Structural Steel required as a result of the change will be made at a unit price per pound. This unit price will be obtained by dividing the Lump Sum bid for Structural Steel by the total estimated weight of Structural Steel shown on the Plans. Reduction in weight due to changes in design will be made at the same calculated rate, and will be deducted from payments due.

2. Prospective Bidders shall verify the estimated weight of Structural Steel before submitting a bid. Adjustments other than for authorized changes will not be made in the Lump Sum bid even though actual weight may deviate from the stated estimated weight.

616.05 BASIS OF PAYMENT.

Payment will be made at the Contract Unit Price as follows:

Pay Item	**Pay Unit**
Structural Carbon Steel AASHTO 270 Grade 36	Pounds
High Strength Low-Alloy Columbium Vanadium Steel AASHTO 270 Grade 50	Pounds
High Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 inch Thick AASHTO 270 Grade 50 W	Pounds
Castings	Pounds
Pipe	Pounds
Sheet Metal	Pounds
Structural Steel	Lump Sum

This payment will be full compensation for all labor, equipment, and materials necessary to complete the work.

SECTION 618
TIMBER STRUCTURES

618.01 DESCRIPTION.

This work consists of constructing timber structures.